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CHAPTER 6: SUMMARY OF FISH FLOW/HABITAT RELATIONSHIPS

This chapter summarizes the information presented in Chapters 2, 3, and 4, and highlights the information on which the flow recommendations were based. Because habitat is one of the main ecological factors directly affected by flows, habitat-use information gathered on the San Juan River, as well as from other Upper Basin areas, was fundamental to developing flow recommendations. The most basic breakdown of this relationship was to determine what flows are needed to create and maintain important habitats on a seasonal basis for different life stages.

A few direct biological responses to the research flows were noted during the 7-year research period, and they are summarized below. A general description of important habitats for each of the native species is given, followed by a short discussion of possible strategies of reducing nonnative species with flow management. Finally, a concise list of important habitat conditions and flow criteria needed to meet these habitat needs is presented.

It is important to note that these relationships are based on conclusions from the SJRIP 7-year research studies, as well as on existing information from throughout the Upper Basin. This information is the best available to date; however, further studies could provide new or contrary information that should be duly considered and incorporated into the flow recommendations when that information becomes available.

RESPONSES TO RESEARCH FLOWS

During the 7-year research period, it was expected that some increases in reproductive success would be seen in Colorado pikeminnow and perhaps razorback sucker. But as discussed in Chapter 4, responses were apparently too small to measure clearly, apparently because of a lack of adults in the system and thus an insufficient number of young to measure a response. The number of young Colorado pikeminnow collected in the river from 1987 through 1997 appeared to show some response to different types of spring runoff conditions. The number of young Colorado pikeminnow collected was very low during years with very low and short spring runoff (1988 through 1991 especially). Number of young also appeared to increase during high-flow years with fairly natural hydrographs, but the relationship is not clear because of differences in the area sampled and the amount of effort expended each year. These relationships do fit the general pattern for Colorado pikeminnow reproductive success seen in other rivers in the Upper Basin (Holden and Wick 1982, McAda and Kaeding 1989, Osmundson and Kaeding 1991, Bestgen et al. 1998).

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Since the advent of research flows, another pattern seen in San Juan River catch statistics was a decline in flannelmouth sucker numbers and an increase in bluehead sucker numbers. In addition, condition factor, a ratio of body weight to length, increased for both species. These changes in the two sucker populations suggest that cobble habitats have improved in productivity (which was not studied) and overall abundance (which was confirmed by the physical studies), making conditions better for bluehead sucker than pre-research, post-dam periods. These same conditions have apparently suppressed flannelmouth sucker density. This change is likely a natural process in response to a more-natural river situation in terms of flow, sediment transport, food availability, and habitat condition.

Bluehead sucker reproductive success, as measured by capture of YOY, was positively correlated with most spring runoff variables, including flow volume and days over 5,000 and 8,000 cfs. This information indicates that the research period flows that mimicked a natural hydrograph have improved reproductive success, as measured by capture of YOY in late summer which has resulted in increased abundance of adults.

In addition, speckled dace abundance in upstream reaches improved since the advent of the research flows, showing significant positive correlations with spring runoff factors of flow volume and days with flows over 5,000 and 8,000 cfs. Speckled dace larval drift also was highest during high runoff years.

The relationships discussed above were generally a result of natural hydrograph mimicry, providing more natural peaks and volumes to the spring runoff by making releases from Navajo Dam match the natural peak of the Animas River. In addition, late summer base flows from the dam were reduced and may also have had a positive effect on survival of YOY native fishes.

The other "response" that was documented during the 7-year research flow period, but was not necessarily related to research flows, was the survival of stocked juvenile/subadult razorback sucker and YOY Colorado pikeminnow. Although both of these species have been stocked in other parts of the Colorado River system, very few of these fish survived (Minckley et al. 1991, Masslich and Holden 1996), making their survival in the San Juan River fairly remarkable. This information strongly suggests that the available San Juan River habitat during the research period was adequate for the size-classes stocked. The subsequent recapture of both species, and the growth and continued survival that has been seen in both species (Holden and Masslich 1997), continues to suggest that the San Juan River can support these species. These stocked fish have allowed the gathering of habitat selection information showing that important habitats include edge pools, eddies, and pools for larger razorback sucker, and backwaters and other low-velocity habitats for YOY Colorado pikeminnow.

Additional habitat selection information was gathered from radio-tagged wild Colorado pikeminnow adults during the 7-year research period. Although not a biological response to the research flows directly, this information provided direct habitat-use data for the San Juan River, including the location of a spawning area.

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The biological information gathered during the 7-year research period was used in several ways to develop flow recommendations. Direct responses that could be correlated to specific flow levels were used to support those flow levels. For example, the improved abundance of YOY bluehead sucker and speckled dace supported a flow recommendation for runoff flows above 5,000 and 8,000 cfs. Other responses were more qualitative, such as the apparent decreased Colorado pikeminnow reproductive success during years with low spring flow or increased success during high, more natural spring runoff flows. The habitat-use information was used to determine which habitats were most important, and then flow/habitat relationships were developed through the physical studies conducted relating development and maintenance of these habitats to flow. The following sections highlight the habitat-use information and the physical relationships that were determined to provide and maintain those important habitats.

GENERAL SUMMARY OF NATIVE SPECIES HABITAT NEEDS

Seasonal habitat use and life history information for the native fishes are shown in Figure 6.1, which is overlain on a typical natural hydrograph so that the relationship between the natural flow pattern and magnitude can be related to important habitat and life history needs. Adults of the two endangered species, Colorado pikeminnow and razorback sucker, prefer eddies, pools, and other relatively low-velocity habitats year-round. These habitats comprise a relatively small portion of the total available habitat in the San Juan River (see Figures 2.7 and 2.8) compared to the Green or Colorado rivers. Adults also use these habitats in more complex portions of the river (areas associated with several different habitat types). Spawning for both species requires relatively clean cobble bars (cobble with adequate interstitial space). Colorado pikeminnow spawning areas appear to have cleaner cobble and are generally less common than the cobble bars used by razorback sucker.

Post-larval Colorado pikeminnow typically prefer backwaters, which comprise a small portion of available habitat in the San Juan River. However, studies during the 7-year research period have demonstrated that YOY Colorado pikeminnow use a variety of other low-velocity San Juan River habitats as well, and the success of stocked YOY Colorado pikeminnow has been better in the San Juan River than anywhere else it has been attempted (Masslich and Holden 1996). These low-velocity habitats must be available year-round, but seem particularly important in the late summer and fall period when post-larval Colorado pikeminnow are in the river. Based on information from the Upper Basin, young razorback sucker life stages seem to prefer flooded areas of low or no velocity that are rich in food. These areas are generally large, inundated portions of the floodplain that may remain flooded much of the year or year-round. Within the current flow regime, such flooded bottomland habitats are not available in the San Juan River, and may never have been available, because of the steepness of the river floodplain. Young razorback sucker have been found in backwaters in the Green River, but individuals in these habitats appear to have lower survival than those in flooded bottomlands. It will not be known if habitat for young razorback sucker currently exists in the San Juan River until a spawning population is established and sufficient larvae are produced for habitat-use studies. Two razorback sucker larvae collected in 1998 in the San Juan

River were found in backwaters. Hopefully, additional larvae and YOY will be found in future years to clarify their habitat use.

Flannelmouth sucker and bluehead sucker also require cobble bars for spawning (Figure 6.1), but these species seem to be much less selective about cobble bar quality than the two endangered species; they tend to spawn throughout the river rather than in selected areas. During nonspawning periods, adult flannelmouth sucker and bluehead sucker use a variety of habitats but commonly use riffles to a greater extent than do the other large-bodied species. Flannelmouth sucker and razorback sucker are known to use backwaters in their early life stages, but young suckers move out of these low-velocity habitats and into mainstream habitats rather quickly as they grow. Speckled dace use smaller substrate (gravel) for spawning and spawn throughout the river. Overall, this species prefers riffle areas or cobble/gravel substrates.

Temperature is also an important habitat consideration, especially related to spawning. Temperature is an important cue for spawning for all of the native species, and flow/temperature combinations are needed for successful spawning. Temperature monitoring in the San Juan River has shown that relatively natural temperature patterns did occur in the river below Farmington during the research period, as well as during pre- and post-dam periods, although Navajo Dam does have a small negative effect on summer temperatures. The increased spring flow releases of the research period, along with colder Animas River temperatures, decreased spring and early summer temperature during peak flows (May, June, and July) compared to the pre- and post-dam periods below Farmington. Mid- and late-summer temperatures were actually slightly higher than the post-dam period likely because of lower base-flow releases. Therefore, mimicry of a natural hydrograph has not necessarily improved the temperature pattern for the native fishes.

In addition to the physical habitat needs of the fishes, habitat quality is also an important factor to consider in flow recommendations. Clean cobble bars for spawning are important for all the native fishes, but especially for Colorado pikeminnow. As discussed in Chapter 4, fine sediments embed larger substrates during low-flow periods. Building cobble bars and keeping them clean (by removing smaller sand and silt particles) are important considerations. Complex river areas are important for both Colorado pikeminnow and razorback sucker adults, especially during the spring and summer. Flows to maintain complexity are important to these fish species. Backwaters need to be relatively clean, and depth of backwaters appears to be important for young Colorado pikeminnow. Backwaters also likely need to be productive to provide the young fish an abundant food supply. As discussed in Chapters 2 and 4, summer and fall storm events can fill backwaters and other habitats with fine sediment, reducing their quality and quantity for native fishes. Higher flows are needed to clean the backwaters and restore their abundance and productivity. Therefore, building backwaters and cobble bars, and keeping them clean, are important habitat quality factors. Flows from 1962 through 1991 did not provide the dynamic natural hydrograph required to provide the habitat quality for a healthy native fish community.

SPECIES LIFE STAGE	WINTER	PRE-RUNOFF	RUNOFF	SUMMER/FALL BASE FLOW
Colorado Pikeminnow				
Adult	Eddies and other low-velocity habitats such as pools in complex river sections.	Eddies and mouths of tributaries, complex areas with warmer water temperature.	Migrate to spawning areas, eddies, slackwaters, and pools.	Spawn in July, cobble bars with clean cobble and adjacent eddies and slackwaters. In fall, eddies, pools, and slackwaters in complex areas for resting and adjacent riffles and
Juvenile (YOY)	Backwaters and other low-velocity habitats.	Backwaters and other low-velocity habitats.	Backwaters, and as the fish become larger, eddies and other habitats with more current.	Larvae drift downstream from spawning areas and use backwaters and other low-velocity habitats.
Razorback Sucker				
Adult	Edge pools and pools in complex river sections.	Spawning migrations, pools, eddies, edge pools in complex areas.	Spawn on ascending limb and near peak on cobble bars. Eddies, flooded vegetation, and pools in complex areas.	Main channel runs in less-complex portions of the river.
Juvenile (YOY)	Poorly understood but likely backwaters and flooded bottomlands.	Poorly understood.	Larvae drift downstream to flooded bottomlands, backwaters, and similar low-velocity, rich habitats.	Poorly understood but likely use flooded bottomlands, backwaters, and other low-velocity habitats.
Flannelmouth Sucker				
Adult	Poorly understood, runs, pools, and riffles in main channel.	Poorly understood, but use runs, pools, and riffles in main channel.	Spawn just after razorback sucker near peak of runoff on cobble bars. Less selective than razorback sucker.	Runs, riffles, and pools.
Juvenile (YOY)	Use habitats with current rather than backwaters and other low-velocity habitats.	Similar to winter.	Larvae drift to backwaters and other low-velocity habitats, juveniles common in secondary channels.	YOY found in backwaters until late summer when they apparently start using habitats with more current such as runs and riffles.
Bluehead Sucker				
Adult	Riffles and other habitats with cobble substrates.	Same as winter.	Same as winter.	Spawn in late June, early July on cobble bars, move back to riffle areas after spawning.
Juvenile (YOY)	Riffles, runs in main channel areas.	Same as winter.	Juveniles common in secondary channels.	Larvae drift downstream to backwaters and other low-velocity habitats, move to habitats with current by early fall.
Speckled Dace				
Adult	Riffles, runs, and other habitats with cobble or gravel substrate.	Same as winter.	Spawn over gravel habitats from late spring to summer.	Larvae found in drift, YOY use backwaters and other low-velocity habitats for a short period before moving to swifter habitats.

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Figure 6.1. The relationship between habitat needs and flow for the native fishes of the San Juan River.

Biological productivity appeared to increase during the 7-year research period, and the condition factor of flannelmouth sucker and bluehead sucker responded to these improved conditions. This suggests that mimicry of the natural hydrograph aided in providing better habitat quality.

RELATIONSHIPS BETWEEN FLOW AND NONNATIVE SPECIES

Flow manipulation, especially the creation of high spring peaks, has been suggested as a way to control some nonnative species. However, this thesis is not supported by the results of the 7-year research period in the San Juan River. It appears that reregulated flows do not have the same impacts on reducing nonnative species abundance as do flood events in unregulated rivers (Minckley and Meffe 1987), or perhaps the San Juan River behaves differently than other southwestern streams. Nonnative species were either not reduced by high spring flows in the San Juan River, or they were reduced for only a short period of time and their numbers appeared to remain relatively consistent during most years. Channel catfish larval drift did show a reduction in catch rate during higher-flow years compared to low-flow years, but this difference was not seen in YOY or juvenile channel catfish. Red shiner abundance in secondary channels in RM 77 to 158 were actually positively correlated to the number of days with flows greater than 8,000 cfs.

Summer flow spikes that perturbated red shiner habitats with flow increase and increased sediment, especially those in secondary channels, appeared to cause some reduction in red shiner and fathead minnow numbers, but the overall effect was temporary. Similar patterns in main channel habitats were not identified. Therefore, although the creation of summer flow spikes may have a short-term effect on secondary channel habitats inhabited by these two nonnative species, there is little evidence that such a flow recommendation would result in significant riverwide reductions in their populations. In addition, a summer flow spike could negatively impact the young of the native species, and may have other negative impacts on productivity and other factors important to the native fish community.

FLOW/HABITAT RELATIONSHIPS

As discussed in Chapter 4, a number of studies were conducted during the 7-year research period that documented changes because of mimicry of a natural hydrograph and addressed the flow levels needed to build and maintain important habitats, especially cobble bars for spawning and backwaters for fish nursery areas. One change measured was a decrease in bed elevation, primarily because of a reduction in the amount of sand in the substrate. This change was likely linked to the increase in biological productivity, the increase in bluehead sucker abundance, and the increase in sucker condition factor as discussed above.

Habitat complexity is also important to Colorado pikeminnow and razorback sucker, but habitat complexity as measured by the number of habitats available in a given river reach was not studied directly. Channel complexity as measured by island count is likely related to habitat complexity since many of the complex river sections have high island count (see Figure 4.15). Channel complexity did increase during 1995, a high-flow year with a peak over 10,000 cfs. In addition, more low-velocity habitats and backwaters were available at base flows of 1,000 cfs or lower than at higher base flows. Base flows during the 7-year research period were generally reduced from the pre-study period years, more closely mimicking natural conditions and resulting in more low-velocity habitats and likely increasing habitat complexity.

Cobble bar construction was studied in detail, and it was concluded that flow of 8,000 cfs for 8 days or more are required for cobble bar construction. Maintenance of cobble bars, primarily scouring of fine sediments from interstitial spaces, occurs at a flow of 2,500 cfs or more. The longer the duration of this flow, the more cobble would be cleaned, but a minimum of 10 days prior to spawning would be needed. Since the various native species spawn from late April or May (razorback sucker) to mid-July (Colorado pikeminnow), a long duration for flows at 2,500 cfs would provide clean cobble for all native species.

Backwaters are important low-velocity habitats, especially for YOY Colorado pikeminnow. Backwater quantity and quality are related to fine sediment amounts. Adequate flushing of backwaters is needed to maximize both quantity and quality. Flows of 5,000 cfs for 3 weeks or more are needed for complete flushing of study backwaters after heavy perturbation by fine sediments.

SUMMARY

Studies during the 7-year research period, as well as information from studies in other portions of the Colorado River system, provided considerable biological and physical information that can be used to develop flow recommendations. Table 6.1 summarizes this information by relating the physical flow parameters to the biological response or habitat needs of the fish community as established by research on the San Juan and other Colorado Basin rivers.

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Table 6.1. Flow requirements needed to produce important biological responses and habitats in the San Juan River.

BIOLOGICAL RESPONSE/HABITAT REQUIREMENT	FLOW CHARACTERISTIC
Reproductive success of Colorado pikeminnow lower in years with low spring runoff peaks, and higher in years with high and broad runoff peaks.	Mimicry of a natural hydrograph, especially during relatively high runoff years.
Decline in flannelmouth sucker abundance, increase in bluehead sucker abundance, and increased condition factor in both species.	Mimicry of natural hydrograph with higher spring flows and lower base flows.
Bluehead sucker reproductive success.	Increased number of days of spring runoff >5,000 and 8,000 cfs correlated with increased success.
Speckled dace reproductive success.	Increased number of days of spring runoff >5,000 and 8,000 cfs correlated with increased success.
Success of stocking YOY Colorado pikeminnow and subadult razorback sucker.	Mimicry of natural hydrograph has provided suitable habitat for these size-classes.
Eddies, pools, edge pools, other low-velocity habitats year-round for adult Colorado pikeminnow and razorback sucker.	Mimicry of natural hydrograph has lowered base flows to provide more low-velocity habitats. Flows >10,000 cfs provide more channel complexity which provides for more habitat complexity.
Flows to cue razorback sucker and Colorado pikeminnow for migration and/or spawning.	Mimicry of natural hydrograph with higher spring flows.
Adult Colorado pikeminnow and razorback sucker use complex river areas.	Flows >10,000 cfs provide more channel complexity which provides for more habitat complexity, lower base flows add to amount of low-velocity habitats.
Clean cobble bars for spawning of all native species, especially Colorado pikeminnow.	Flows >8,000 cfs for 8 days to construct cobble bars, and >2,500 cfs for 10 days to clean cobble bars, during spring runoff.
Backwaters and other low-velocity habitats are important nursery habitats for Colorado pikeminnow and other native fishes.	High spring flows create conditions for backwater formation, low base flows allow them to appear in late summer and fall, flows >5,000 cfs for 3 weeks create and clean backwaters.
Flooded bottomlands appear to be important nursery areas for razorback sucker, but other habitats may be used in the San Juan River.	Overbank flows (> 8,000 cfs) increase flooded vegetation, and backwaters formed in association with edge features maximize on receding flows of 8,000 to 4,000 cfs.
Temperatures of 10 to 14 EC at peak runoff for razorback sucker spawning and near 18 to 20 EC at bottom of descending limb for Colorado pikeminnow spawning.	Proposed releases from Navajo Dam are too cool to replicate pre-dam temperature timing, but temperatures are above spawning threshold for Colorado pikeminnow during the correct period.
Reduction of nonnative fish abundance.	Most nonnative fishes did not decrease during research period, summer flow spikes reduce numbers of red shiner in secondary channels in the short term.

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